ORIGINAL RESEARCH

Blood Lactate Response to the Canadian Aerobic Fitness Test (CAFT)

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Catalogue Data:
BELL, D.G., LEE, S.W., JACOBS, I. (1992). Blood Lactate Response to the Canadian Aerobic Fitness Test (CAFT). **Can. J. Spt. Sci.** 17:1 14-18.

ABSTRACT

This study evaluated the blood lactate (LA) response to stepping exercise, specifically the Canadian Aerobic Fitness Test (CAFT). It also compared the correlation between either LA or heart rate (HR) at a given stage of the CAFT and directly measured maximal aerobic power ($\dot{V}O_2$max). A total of 137 male Canadian Forces (CF) personnel between the ages of 18 and 53 years participated in this study. The LA concentration after each stage of the CAFT was measured in all subjects from blood sampled from the fingertip. Seventy-eight of these subjects also had their $\dot{V}O_2$max measured directly during a maximal treadmill run. The results showed that increasing stages of the CAFT were associated with exponentially increasing LA. At Stage 5, LA concentration ranged from 1.0 to 7.0, with a mean of 2.6 mmol·L^{-1}, while HR ranged from 72 to 192 with a mean of 132 beats. When the LA and HR measures at Stage 5 of the CAFT were compared for their ability to predict $\dot{V}O_2$max, the correlation between lactate and $\dot{V}O_2$max was –0.71 ($p<.001$); between HR and $\dot{V}O_2$max it was –0.36 ($p<.01$). These results suggest that LA is a better predictor of $\dot{V}O_2$max than HR.

Key words: lactate; aerobic power; exercise; $\dot{V}O_2$max; physical fitness.

RÉSUMÉ

Cette étude s'intéresse à la production sanguine de lactate au cours d'un exercice progressif sur banc ergométrique, celui du Test Canadien d'Excellence Aérobie. Elle présente également la relation entre la concentration de lactate ou la fréquence cardiaque à une étape précise de l'exercice ainsi qu'à la mesure directe du $\dot{V}O_2$max. Cent trente-sept hommes du personnel des Forces Canadiennes et dont l'âge varie entre 18 et 53 ans participent à l'étude. La concentration de lactate est obtenue à chaque étape de l'exercice d'après l'analyse d'échantillons de sang veineux du bout du doigt. La puissance maximale aérobie de 78 de ces sujets est évaluée sur tapis roulant. La concentration de lactate augmente exponentiellement au fil des étapes du test progressif. À la 5^e étape, la concentration varie entre 1,0 et 7,0 mmol/L (M = 2,6 mmol/L) et la fréquence cardiaque se situe entre 72 et 192 battements par minute avec une moyenne de 132. La corrélation entre la concentration de lactate à la cinquième étape et le $\dot{V}O_2$max est de –0,71 ($p<0,001$) et celle entre la fréquence cardiaque à la même étape et le $\dot{V}O_2$max est de –0,36 ($p<0,01$). La concentration de lactate apparaît donc comme une meilleure mesure de prédiction du $\dot{V}O_2$max que la fréquence cardiaque.

Mots-clés: lactate; puissance aérobie; exercice; $\dot{V}O_2$max; excellence physique.

Introduction

The Canadian Standard Test of Fitness (CSTF) was developed over two decades ago (Bailey et al., 1976; Jetté, 1979; Shephard, 1967). It includes assessments of maximal aerobic power ($\dot{V}O_2$max), muscular endurance, muscular strength, flexibility, and body composition. A stepping exercise test, called the Canadian Aerobic Fitness Test (CAFT), is used to estimate $\dot{V}O_2$max (Fitness and Amateur Sport, 1986). Depending upon the stage of the step test to which an individual can progress and the heart rate attained during that stage, an individual's $\dot{V}O_2$max is calculated and a gross fitness category is assigned. The individual's age, weight,

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and sex are also taken into consideration when calculating the $\dot{V}O_2$max. The CAFT was originally developed as a tool to motivate Canadians to determine and enhance their fitness.

Recently the Canadian Forces (CF) adopted the CSTF procedures for assessing fitness in their personnel. For this population, low scores from these assessments may limit career progress and/or result in dismissal. The accuracy of the test battery thus assumes considerable importance. Since the $\dot{V}O_2$max is predicted and not measured directly, it is subject to prediction error; thus there has been much debate about the accuracy of this procedure. This is exemplified in the literature by the moderate correlations reported between direct measures of $\dot{V}O_2$max and the CAFT predicted $\dot{V}O_2$max values (Bell and Allen, 1983; Bonen et al., 1977; Jetté, 1979; Shephard et al., 1979). Therefore a more precise method of predicting maximal aerobic power would be advantageous to the CF.

The blood lactate response to submaximal exercise has been repeatedly shown to be an accurate means of evaluating aerobic fitness (Jacobs, 1986; Jacobs et al., 1983). One military force, Norway's, has adopted a lactate based exercise test for their fitness evaluation of all new conscripts (Helgerud, 1988). This test consists of 6 to 7 minutes of submaximal walking at a standard velocity on a treadmill. At the end of the walk a blood sample is obtained from the fingertip and immediately analyzed with an automatic lactate analyser. The conscript is assigned a fitness level based on the lactate concentration after exercise, that is, the lower the concentration, the more fit the conscript.

The present study was undertaken for two reasons: first, to determine the blood lactate response to the CAFT, and second, to compare the correlation between directly measured $\dot{V}O_2$max and HR at a specific stage of the CAFT to the correlation between directly measured $\dot{V}O_2$max and LA sampled during the CAFT at the same stage in CF male personnel.

Methods

SUBJECTS AND TEST PROCEDURES

A total of 137 CF male personnel ages 18 to 53 years volunteered to participate in the study. They represented a wide spectrum of age and physical fitness levels, ranging from the very fit to the very unfit. Their physical characteristics, including their predicted and directly measured $\dot{V}O_2$max, are presented in Table 1.

Before beginning the tests, each subject completed the Physical Activity Readiness Questionnaire, PAR-Q (Chisholm et al., 1978) and signed an informed consent form. In order to obtain sufficient lactate data at the lower stages of the CAFT, all individuals started at Stage 2 except for those over 50 years of age who had the option of starting at Stage 1. The subjects were allowed to proceed to the next stage as long as their heart rate was below the recommended ceiling level for the first stage for their age, as described in the CSTF operations manual (Fitness and Amateur Sport, 1986). Immediately upon completion of each stage, HR was measured for 10 seconds, as per the testing protocol, and a 20-µl capillary blood sample was taken from a fingertip. Based on the HR measured during the maximum allowable exercise stage, their $\dot{V}O_2$max was predicted using the CAFT aerobic calculator.

Table 1 Physical Characteristics of the Subjects Who Participated in the CAFT and the Maximal Treadmill Test

	CAFT group (n=137)	Treadmill group (n=78)
Age (yrs)	31.4 ±8.4	28.5 ±7.8
Weight (kg)	78.9 ±11.5	79.9 ±11.8
Height (cm)	174.4 ±7.3	175.5 ±7.2
Predicted $\dot{V}O_2$max* ($ml \cdot kg^{-1} \cdot min^{-1}$)	40.1 ±4.3	43.2 ±4.1
Measured $\dot{V}O_2$max** ($ml \cdot kg^{-1} \cdot min^{-1}$)		49.8 ±8.7

*Predicted from CAFT results; **measured from treadmill test.

The blood sample taken after each stage of exercise was immediately expelled into 200 µL of cold 0.4-M perchloric acid and kept on ice until transported to a freezer where it was stored at –80°C. The samples were assayed for their lactate concentration using an enzymatic fluorometric method (Maughan, 1982).

Seventy-eight of the subjects volunteered to perform a $\dot{V}O_2$max test on the treadmill. Heart rate during the treadmill run was monitored with either a sport tester or via electrocardiograph (Cardisuny model 501D) from bipolar ECG leads. Oxygen consumption, carbon dioxide production, and ventilation were monitored with an automated metabolic cart (Beckman Sensormedic) every 30 seconds. After a 2-min familiarization walk at 4.8 km/h and a 3-min warm-up walk at the test speed of 5.33 km/h, the treadmill grade was raised 2% every 3 minutes until RQ reached 1.0. Thereafter the grade was raised 2% every minute until $\dot{V}O_2$max. Total test duration ranged from 9 to 24 minutes. $\dot{V}O_2$max was defined by a plateau in oxygen consumption with an increasing minute ventilation, or by subject volitional exhaustion. The highest value in oxygen consumption measured during the test was considered as the $\dot{V}O_2$max. The metabolic cart was calibrated with known gas samples at the beginning of the day and after every subject had completed his run.

TREATMENT OF DATA

All statistical processing was performed using BMDP software (Dixon, 1981). Pearson product correlations were calculated and a two-tailed test was used to evaluate the significance of the correlation. Stepwise regression analysis was used to derive a regression equation for $\dot{V}O_2$max from the lactate and heart rate values measured at Stage 5 of the CAFT. Other standard statistical measures were used to

obtain means and standard deviations. Significance was set at the 0.05 level.

Results

Figure 1 shows the frequency distribution of the blood lactate concentrations at Stages 2 through 6 of the CAFT. In Table 2 the mean, standard deviation, and range of LA at each of the five stages are listed. Values ranged from 0.5 to 7.0 mmol·L^{-1}. Table 3 shows the correlations between the directly measured $\dot{V}O_2$max and the CAFT Stage 5 HR, age, weight, and LA. LA produced the highest correlation, which was significant beyond the 0.001 level. Table 4 shows the multiple correlations derived from a stepwise regression to predict treadmill $\dot{V}O_2$max. The equation to predict $\dot{V}O_2$max was as follows:

$$\dot{V}O_2\text{max} = 74.03 - (0.35 \cdot \text{age}) - (0.05 \cdot \text{wt}) - (3.57 \cdot \text{LA}) - (0.01 \cdot \text{HR})$$

Discussion

The purpose of this study was to evaluate the feasibility of using the blood lactate response to the CAFT in evaluating aerobic fitness. It is apparent from the blood lactate response (Figure 1) that stepping exercise with a progressively increasing protocol markedly raises blood lactate levels in the typical exponential fashion associated with other exercise modalities. The range of blood lactate concentrations measured indicates that the CAFT raises lactate values to within the 2–5 mM range. This range has been demonstrated to be appropriate for predicting endurance performance (Jacobs, 1981; Jacobs et al., 1983). It therefore appears feasible that

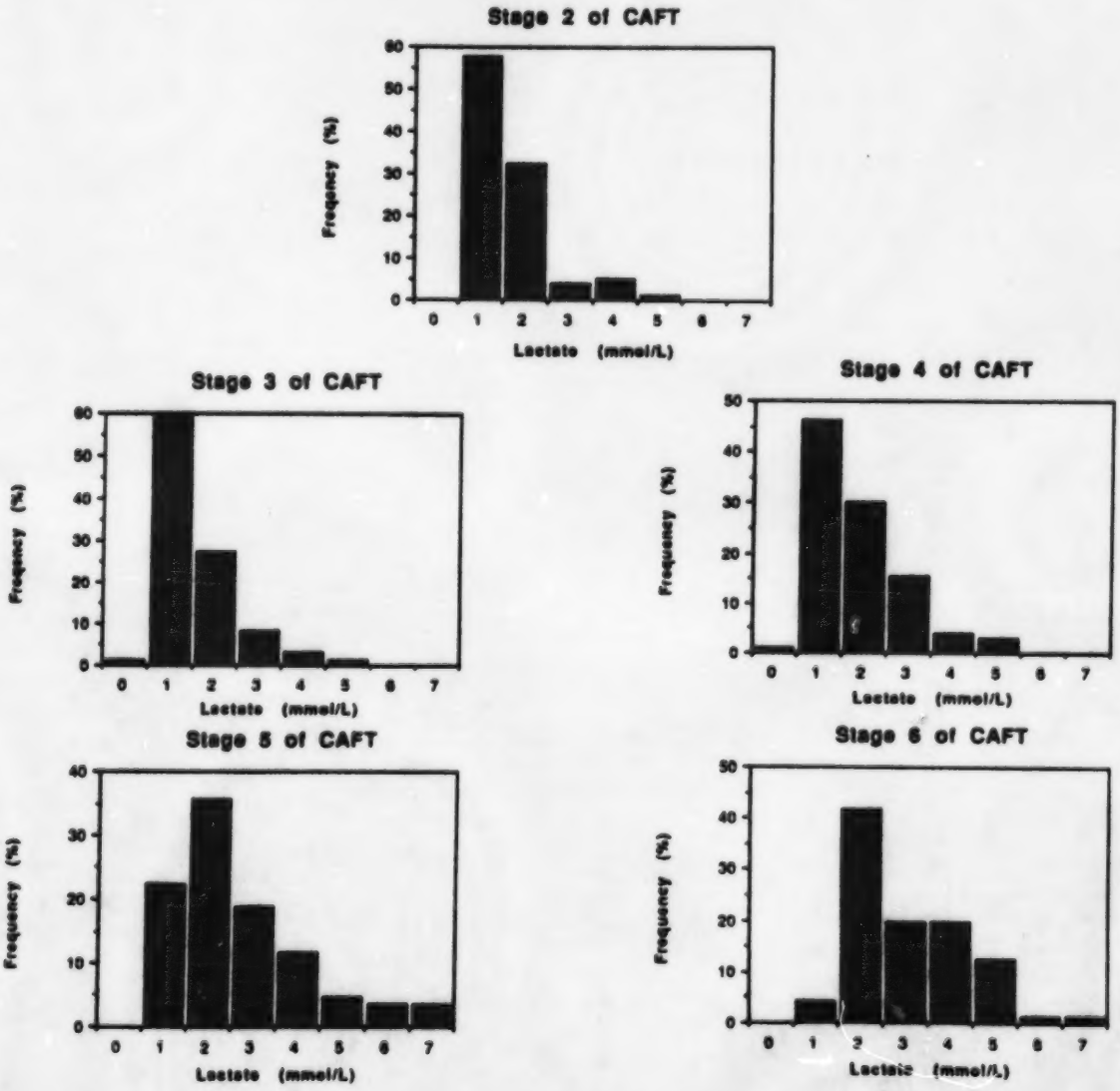

Figure 1. Frequency distribution of blood lactate concentrations at Stages 2 through 6 of the CAFT.

Table 2 Blood Lactate (mmol·L^{-1}) at Each Stage of the CAFT

Stage	No. of samples	Lactate	Range
2	137	1.6 ±0.8	0.6–4.8
3	135	1.65 ±0.9	0.5–4.6
4	137	1.9 ±1.1	0.5–5.2
5	112	2.6 ±1.4	1.0–7.0
6	72	3.0 ±1.3	1.3–5.6

Table 3 Pearson Product Correlations Between the Measured $\dot{V}O_2$max and the CAFT Measures at Stage 5 and Blood Lactate

Variable	r
Lactate	–0.71***
Age	–0.61***
Weight	–0.22*
Stage heart rate	–0.36**

*Significant beyond 0.05 level; **significant beyond 0.01 level; ***significant beyond 0.001 level.

Table 4 Multiple Correlations (R) From Stepwise Regression for Predicting Directly Measured $\dot{V}O_2$max From CAFT Variables and Lactate

Variable	R	R^2	Change in R^2
Lactate	0.710	0.504	0.504
Age	0.761	0.579	0.075
Weight	0.764	0.584	0.005
Heart rate	0.764	0.584	0.000

blood lactate measures could be used to evaluate aerobic fitness in conjunction with the CAFT without altering the test protocol presently employed.

Further reasons and advantages for using blood lactate are as follows: First, it has been shown that lactate related variables account for a larger proportion of the variation in endurance exercise performance than any other variable traditionally measured in the exercise laboratory, including the measurement of $\dot{V}O_2$max (Jacobs, 1986). Second, blood lactate can be easily sampled and measured. Third, there is a small but significant proportion of CF personnel and the general population who are presently not tested because they are being treated with medication that alters the normal HR response to exercise, thus invalidating the use of HR in predicting $\dot{V}O_2$max. Such medications, in particular β-blockers, do not markedly alter the LA response to submaximal exercise (Kaiser, 1984).

This study was also undertaken to compare the strength of the prediction of $\dot{V}O_2$max determined by HR with that determined by LA. Only the data for the 78 male subjects who completed both Stage 5 of the CAFT and the maximal treadmill test were used to evaluate these correlations. The highest correlate for $\dot{V}O_2$max was blood lactate, followed by age, heart rate, and weight (Table 3). Table 4 shows the multiple correlations derived from a stepwise regression to predict treadmill $\dot{V}O_2$max. Again only the data for the 78 male subjects who completed both Stage 5 of the CAFT and the maximal treadmill test were used. The independent variables used in the regression included lactate plus the three other variables normally used in the CAFT, that is, heart rate, age, and weight. The variables are entered into the regression equation according to the strength of their ability to predict treadmill $\dot{V}O_2$max. The multiple R is reported as each variable is added into the prediction.

The greatest proportion of the predictability comes from lactate, followed by age, weight, and then heart rate. Heart rate adds very little to the strength of the multiple correlation coefficient. The results suggest that lactate measures, rather than heart rate measures, are better predictors of $\dot{V}O_2$max and that replacement of the present heart rate based test with a test involving blood sampling is very feasible. Furthermore, the results support the conclusions of Jacobs (1986), Jacobs et al. (1985), and Kumagai et al. (1982) which suggest that the lactate response to exercise is an excellent predictor of aerobic fitness.

Another factor to support the use of lactate deals with changes in $\dot{V}O_2$max as a result of training. Recently Bell and Jacobs (1986) reported that the CAFT was insensitive to directly measured training-induced changes in $\dot{V}O_2$max in flight crews who had been engaged in 12 weeks of circuit training. The results of several studies (Denis et al., 1982; Jacobs, 1986; Sjödin et al., 1982) suggest that lactate is a more sensitive indicator of training adaptation than is directly measured $\dot{V}O_2$max. Particularly when an individual's livelihood may be affected, as is the case in the military, it would be prudent to employ as accurate an evaluation as possible. There are of course factors that confound the interpretation of the lactate response to exercise (Graham, 1984), but arguably these are fewer and easier to control than the many factors affecting HR.

Figure 2 depicts the lactate concentrations at the various CAFT stages for three groups: those who completed up to Stage 4 (Four), those who completed up to Stage 5 (Five), and those who completed up to Stage 6 (Six). The group labeled Six were the most fit individuals; they show the expected reduced lactate response to similar workloads when compared to the other groups. This figure also shows the exponential curves typically seen for lactate during progressively increasing treadmill or bicycle exercise (Jacobs and Sjödin, 1985; Withers et al., 1981). It may also be concluded that the CAFT accurately grouped subjects if the lactate response was used as a validation criteria.

One other point of interest from Figure 2 concerns the initial lactate levels, which averaged 1.85 mmol·L^{-1}. This

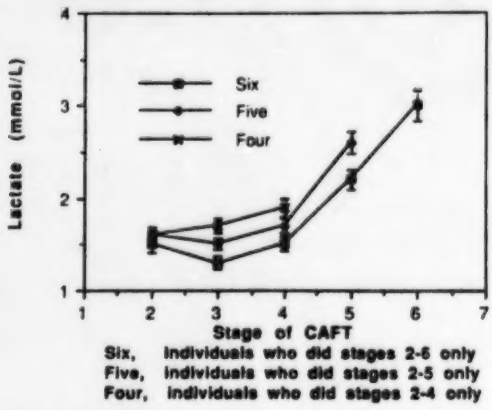

Figure 2. Blood lactate concentrations in subjects who completed four, five, or six stages of the CAFT. Data are mean ± SEM.

concentration is quite high for resting values, which suggests that these subjects did not come to the test site in a normal rested state. Although their resting heart rates were sufficiently low, indicating that they could proceed with the step test, the high resting lactate levels could have confounded the test. By having the subjects start at a low stage on the step test (i.e., Stage 2), lactate concentration was decreased to normal levels before the exponential increase associated with the higher intensities occurred.

In summary, in those situations in which fitness levels are important to career progress such as in the CF, the present report indicates that the measure of blood lactate would enhance the prediction of aerobic power. The applicability of measuring LA in the field situation may seem a little extensive; however, when maximal treadmill testing is the alternative, a strong case can be made for the LA measure. The procedures for blood sampling and analysis are simple. The cost of the equipment is moderate; equipment maintenance is minimal. And finally, the results could possibly save the CF thousands of man hours with regard to reevaluation and remedial training.

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ACKNOWLEDGMENT

The authors would like to thank Mr. J. Pope, Ms. M. Young-Hong, and Mr. A. Klugerman for their technical assistance.

Received September 11, 1990; accepted in final form January 31, 1991.